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PAPERS ON THE RELATION OF THE ATMOSPHERE TO HUMAN COMFORT

The following group of five papers represent an experiment in the treatment of climatic data. Even two decades ago climatologists had carried the separation of climatic data into the elements so far that a swing toward synthesizing them was made. Prof. R. De C. Ward has vivified American climates in his extensive discussion, The Weather Element in American Climates.[1] The next step was, obviously, to express our weather in terms of a scale of human comfort, or at least to describe climates with the aid of frequencies of well-recognized weather types. The first two papers are but suggestions of lines along which may be developed a satisfactory scale of human comfort in terms of weather. The other three papers illustrate three types of treatment of climate as the aggregate or succession of daily weather.—*C. F. B.*

[1] Annals of the Association of American Geographers, Vol. IV, pp. 3-54, 1915.

THE COOLING OF MAN UNDER VARIOUS WEATHER CONDITIONS

By C. F. BROOKS

[Clark University, Worcester, Mass., 1922]

Dr. Leonard Hill, in his recent work, The Science of Ventilation and Open Air Treatment,[1] has compiled a great deal of information concerning the rate at which a man cools under various weather conditions. Valuable though this material is, however, the various experiments and observations have not been coordinated into any systematic statement of the cooling power of the atmosphere on man.

In this paper an attempt has been made to reduce these observations to a mathematical form, in an effort to find a basis by which weather might be classified according to its relation to human comfort. No claim is made that the formulæ and tables deduced are of satisfactory accuracy, but merely that the method employed and the application made (see Donnelly's paper, following) justifies the collection of more experimental data so that accurate studies of the relations of weather to man may be made on these lines.

The human cooling data presented by Hill are of three sorts: (1) Calorimetric observations by Lefevre, (2) metabolism (Douglas bag) observations by Hill and his associates, and (3) human comfort observations in conjunction with those of the katathermometer and various weather factors.

(1) The calorimetric observations by Lefevre were for various temperatures between −1 and +20° C., on a subject naked and clothed, with wind velocities of 3.5 meters per second, and on a subject clothed, with a wind velocity of 1 meter per second. (Tables 15 and 16, Hill, Pt. I, pp. 45–46.) These data represent the actual output of heat from the man's body (C_m). They may be given fairly accurately by the following formula (for clothed man):

$$C_m=\left(\frac{19.5-\theta_1}{603}+\frac{3.0+\theta_1}{222}\sqrt{v}\right)(0.10+0.40/\sqrt{v})\theta_1+0.35$$

in which θ_1, is the depression of the air temperature below 36.5° C., v the wind velocity in meters per second, and the last term the assumed loss of heat from the lungs and skin owing to evaporation (in millicalories per square centimeter of body surface per second). A table showing smoothed values derived from this formula is presented in the second paper of this group.

(2) The metabolism observations by Hill and his associates are given principally in Tables 31 and 32, Part I, pages 90–93. Here are presented the heat production of various subjects sitting out of doors in all kinds of weather at all seasons (H_m). Unfortunately, the data are not sufficiently extensive to be expressible in well-founded mathematical formulæ. Those obtained from plotted data, to which lines were fitted by the eye rather than by the least square method (which was not used because of the insufficiency of the data) are as follows: $H_m=(0.025+0.004\sqrt{v})\ (0.10+0.40/\sqrt{v})\ \theta_1+0.35$ for velocities 0.25 to m/s. $H_m=(-0.016+0.08\sqrt{v})\ (0.10+0.40/\sqrt{v})\ \theta_1+0.35$ for velocities above 1 m/s. Except in warm weather, the rate of heat production by Hill and his subjects is less than the rate of heat emission by Lefevre's subjects.

(3) The comfort indications given in the latter portions of Hill's Part I have used as a rough check, when extrapolations were made, to derive tables for comparing the cooling power of various weather conditions.

With these data of heat emission, heat production, and comfort, it appeared possible to construct tables which would show for any weather conditions approximately the rate at which a man will cool. (See the second paper of this group.)

The indications of the katathermometer have not shown any simple relation to man's cooling. The reasons are several:

Man's heat regulatory apparatus varies with respect to:
First. The flow of blood through the surface capillaries;
Second. The rate of evaporation from the skin;
Third. The conductivity of the skin; and
Fourth. The temperature of the skin.

There are differences between subjects and between the basic conditions of the same subject at different times. Hill found, however, that if the kata had a temperature like that of the subject's cheek, the rate of cooling of the kata would be roughly 6.5 times the rate of heat production of a clothed man.

[1] Pt. I, Medical Research Committee, Spec. Report Ser., No. 32, 1919; Pt. II, Medical Research Council, Spec. Report Ser., No. 52, 1920, London, H. M. Stationery Office.